

**Smart Rivers 2019 Conference**  
**/ September 30 - October 3, 2019**  
**Cité Internationale / Centre de Congrès**  
**Lyon FRANCE /**

**Ref. author:**

**Roeland Adams – IMDC nv**  
Van Immerseelstraat 66, 2018 Antwerp, Belgium  
[roeland.adams@imdc.be](mailto:roeland.adams@imdc.be)

**Co-authors:**

**Sebastien Page – IMDC nv**  
Van Immerseelstraat 66, 2018 Antwerp, Belgium  
[sebastien.page@imdc.be](mailto:sebastien.page@imdc.be)

**Marc Mansuy – Ghent University**  
[Marc.Mansuy@UGent.be](mailto:Marc.Mansuy@UGent.be)

**Maxim Candries – Ghent University**  
[Maxim.Candries@UGent.be](mailto:Maxim.Candries@UGent.be)

**Katrien Eloot – Flanders Hydraulic Research**  
[katrien.eloot@mow.vlaanderen.be](mailto:katrien.eloot@mow.vlaanderen.be)

**Sarah Doorme – IMDC nv**  
Van Immerseelstraat 66, 2018 Antwerp, Belgium  
[sarah.doorme@imdc.be](mailto:sarah.doorme@imdc.be)

**Xavier Thorel – Voies Navigables de France**  
37, Rue du Plat, 59034 Lille, France  
[Xavier.Thorel@vnf.fr](mailto:Xavier.Thorel@vnf.fr)

**Claire Labourie – Voies Navigables de France**  
37, Rue du Plat, 59034 Lille, France  
[claire.labourie@vnf.fr](mailto:claire.labourie@vnf.fr)

**Keywords:**

Inland navigation, Nautical design guidelines, Real time simulations, Traffic flow modelling

**A comprehensive characterization of the nautical accessibility and  
traffic flow of the ECMT class Va inland waterway network of Nord-  
Pas-de Calais, France**

## **Introduction**

The Nord-Pas-de-Calais ECMT Class V network will play a major role in linking the Canal Seine Nord Europe to the ports of Dunkirk, the inland navigation network of Flanders and Wallonia (Belgium) and its connected ports in the Scheldt-Rhine delta such as Ghent, Antwerp and Rotterdam. In the anticipation of the opening of the Canal Seine Nord Europe, the Flemish and Wallonian waterway managers are upgrading their networks to ECMT class Va and, in some cases, class Vb. The existing Nord-Pas-de-Calais Class V network (also known as the “Canal à Grand Gabarit”) is old and does not fully meet the modern geometric standards for canal design and construction. In order to prepare the network for the expected increase in traffic due to the opening of the Seine-Scheldt connection, Voies Navigables de France (VNF) has commissioned a comprehensive analysis of the Grand Gabarit waterway network based on nautical studies.

Moreover, the expected increase in traffic may strongly impact the fluidity of the network. In order to better understand and tackle potential bottlenecks, VNF has also commissioned a traffic flow model to study the traffic flow on the ECMT class V waterway network of the Nord-Pas-de-Calais.

## **The Seine-Scheldt project and the network**

The ECMT class V network of Nord-Pas-de-Calais consists of three distinct branches: Dunkerque - Bauvin, Bauvin - Halluin, and Bauvin - Mortagne-du-Nord. The first canal assures the connection with the Port of Dunkirk. The second canal largely follows the canalized Deûle and Lys Rivers and links the system with the Port of Ghent and more northerly ports in Belgium and the Netherlands through the main axis of Seine-Scheldt liaison of Belgium (the Lys River). The third canal connects the system with the Scheldt River, linking again with the northerly ports, but also the Central Walloon Canal and the Meuse basin. This section will host the junction with the new Canal Seine Nord Europe.

While the Belgian canals and rivers are being upgraded using modern design guidelines and the Canal Seine Nord Europe is being designed accordingly, the Canal à Grand Gabarit, the backbone of the Nord-Pas-de-Calais network, dating largely from the 1950s and 60s, does not fully comply with these guidelines. Although the canal and lock complexes are dimensioned to allow push barge convoys up to 143 m x 11.4 m, it is not clear whether the locks and canal can accommodate the anticipated growth in traffic due to the construction of the new connection and the upgrading of the connected rivers and canals. It is also not clear what the impact of the increase in traffic on travel and waiting times will be. The anticipated increase in travel and waiting time is generated at locks and at critical narrow canal sections which only allow alternating traffic.

## **Trajectory analysis**

IMDC, together with Flanders Hydraulic Research and the Maritime Technology Division of the University of Ghent, has developed an approach of combined desktop analysis and real time navigation simulations to characterise the performance of the network for different ship types. The combination of both tools allows to reduce the cost of the nautical analysis of waterway. The desktop study uses existing design guidelines to check section geometry and to define accessibility for different ship combinations at ease and safety levels. The nautical characteristics and accessibility of sections liable to be upgraded are checked with real-time nautical simulations. In return, the nautical simulations also enable the verification of the validity of the nautical design principles and help improve the design guidelines and desktop approach.

Finally the results are used to define accessibility conditions for the network (either two-way or alternate traffic stretches for specific ship classes) and to identify bottlenecks requiring infrastructural measures. At this point, a feedback to the concurrent traffic flow study allows the evaluation of the benefits of potential measures and to effectively decide on their implementation.

### Trajectory analysis: desktop study to select cases for real time nautical simulations

État des lieux de la commune

01/11/2024/07

04/11/2024/07

Date de la commune

01/11/2024

Date de la commune

04/11/2024

Section

Secteur : Mairie - Marly-sur-Orde

01/11/2024/07

Version

2.0

Auteur

Mairie de Marly-sur-Orde

Révision

04/11/2024

Approbation

04/11/2024

Etude de trajectoire pour le réseau navigable du Nord Pas de Calais

Section 20 (PK5.8-6.3)

Accessibilité étudiée: Vo-IV

Synthèse

Accessibilité étudiée: Vo-IV

Conditions hydrologiques/autres :

Montagne

Loire

Dependence

IV

IV

IV

IV

IV

IV

IV

IV

IV

IV

IV

IV

IV

IV

IV

IV

IV

IV

IV

IV

IV

IV

IV

IV

IV

IV

IV

IV

IV

IV

IV

IV

IV

IV

IV

IV

IV

IV

IV

Synthèse

Synthèse de l'analyse de trajectoire (synthèse)

Synthèse de l'analyse

# km

Réseau

Différence

Commentaires des données

001

2

2

-

002

2

2

-

003

2

2

-

004

2

2

-

005

2

2

-

006

2

2

-

007

2

2

-

Cette section devrait être étudiée mais n'est ni en état de voir ni en état de voir. Il s'agit d'une section qui devrait être étudiée mais n'est ni en état de voir ni en état de voir. Il s'agit d'une section qui devrait être étudiée mais n'est ni en état de voir ni en état de voir.

Commentaires de l'analyse :

Commentaires de l'analyse :

Commentaires de l'analyse :

Commentaires de l'analyse :

Commentaires de l'analyse :

Commentaires de l'analyse :

Commentaires de l'analyse :

Commentaires de l'analyse :

Analyse des résultats

Indicateurs de résultats

# km

Vitesse [km/h]

Engagement sous route [m]

Distance au contour # 1 [m]

Distance au contour # 2 [m]

Ressource propultrice [groupe]

Ressource propultrice [détail]

Ressource gouvernail

Résultat moyenne

Variation moyenne du gouvernail [°]

Distance entre bateaux [m]

001

7.6

0.5

0.5

0.5

44%

100%

0%

1.64

9.7

002

8.0

0.7

0.7

0.7

44%

100%

0%

1.55

9.5

003

8.5

1.0

1.0

1.0

50%

100%

0%

1.95

9.9

004

7.8

1.0

1.0

1.0

43%

100%

0%

1.70

9.7

005

7.9

0.8

0.8

0.8

46%

100%

0%

1.35

9.1

Voie déviée

001

8.0

1.0

1.0

1.0

43%

100%

0%

1.70

9.7

002

7.8

1.0

1.0

1.0

43%

100%

0%

1.70

9.7

003

7.9

1.0

1.0

1.0

45%

100%

0%

1.81

9.9

004

7.9

1.0

1.0

1.0

43%

100%

0%

1.70

9.7

005

7.5

1.0

1.0

1.0

53%

100%

0%

1.97

10.1

Conclusion

Conclusion de l'analyse

# km

Conclusion de l'analyse

Commentaires de l'analyse

001

Commentaire sans commentaire

002

Commentaire acceptable à l'heure actuelle, conditions météo du gouvernail

003

Commentaire sans commentaire

004

Double écoule via possible

005

Il y a une déviation pour un double sens sur la section 20. Variations météo du gouvernail

Accessibilité retenue: Vo-Va

Figure 1: example of simulation result sheet (in French), combining visuals of the sailed trajectory and an appreciation of the accessibility level using a colour scale – larger scale figure in last page

As mentioned above, the first step of the trajectory analysis consisted in a desktop study, in which geometrical rules were tested on the current canal sections. Rules have been defined to classify waterway sections for ease and safety navigation levels. This allowed the identification of stretches allowing ship encounters (of same or different classes) for a given navigation level (ease, safety) on the one hand, and the identification of stretches allowing alternating traffic only on the other hand.

Based on real time nautical simulations, encounters falling below the ease level (but above safety) have been divided into categories with fair and limited chance to be upgraded to a higher accessibility class without structural measures. The nautical simulation either led to: a confirmation of the accessibility class, the possibility of a (conditional) upgrade, or the deduction of navigation conditions. In a few cases the rules applied in the desktop study were challenged. This led to a review of the strategy for interaction between the desktop study and the nautical simulations.

Additionally, a selection of nautical simulations across the entire range of possible geometrical conditions (canal width, bend radius), allowed to univocally determine allowable encounters. This finally led to a reduction of number of simulation required to determine the accessibility level of the entire network.

## Traffic flow model

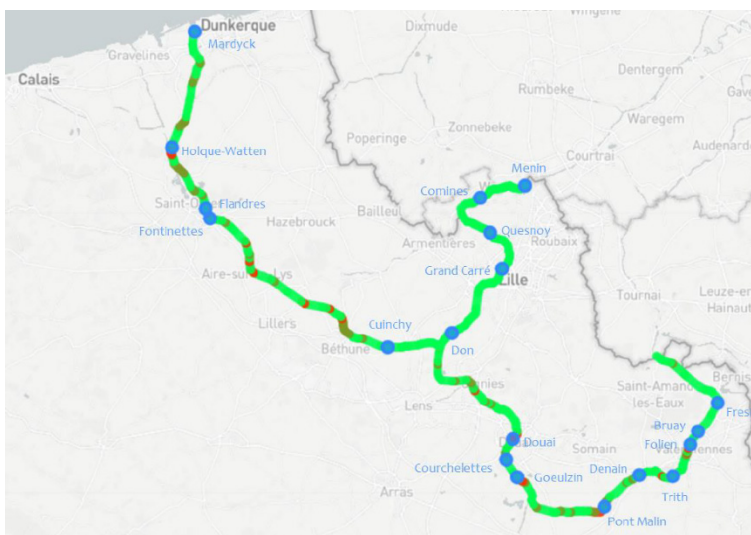


Figure 2: network, locks (blue dots), reduced accessibility sections (red), from online model and result viewer

Until recently, only models for individual lock complexes or unbranched networks existed. Models for branched network were not available as the used model software did not allow for the combination of branches. The traffic model for the Grand Gabarit network is constructed using IMDC Waterways, a software that allows a detailed definition of branched waterway networks.

The model allows the definition of links and nodes, respectively allowing the definition of the geometry of the waterway and the evaluation of ship encounters. Traffic can be inserted on each individual node, under the form of time series of ship journeys defined by the ship characteristics (length, width, draught, etc.) as well as the journey's origin and destination. As an

additional character of the ship journey, ships are either removed from the system after reaching their destination, or may be moored (temporarily) at intermediate destinations, potentially leading to a partial narrowing of the waterway geometry.

Ship encounters can be either defined by classical access rules such as those defined by regulations or by geometric rules. In the Nord-Pas-de-Calais case, the accessibility of the nautical desktop study has been used as input to the traffic model. The traffic model will be further adapted as more results from the real-time simulations become available.

Ship speed can either be imposed (regulations) and/or calculated based on the characteristics of the ship and the canal section geometry (Schijf's approach). Here as well, the model will be refined using the results of the real time simulations, not only to correct speed of individual ships, but also to adapt speed in case of encounters and in bends.

Traffic is generated with an improved generator allowing the definition of different statistical distributions to define inter arrival times. In this study, an Erlang distribution ( $k=5$ ) is used.

Powerful pre and post processing modules allow the creation of statistics illustrated in tables and graphs to analyse the capacity of the network, identify bottlenecks and define traffic saturation.

### Traffic flow simulations

The model is capable of reproducing the traffic fluxes based on available Origin-Destination lists and lock registries. Traffic analysis shows clear differences in fleet distribution between the different branches. For future projections not only the traffic intensity but also the fleet structure is changed.

Hourly distributions have been analysed at different locks. A sensitivity analysis was performed to select parameters which led to hourly distribution of arrivals times at the locks matching the observations, as this strongly influences waiting times.

Simulated travel and waiting times correspond well with experience of the waterway managers. Waiting times practically only occur at the lock complexes, and are most important on the branches with the larger ship sizes (Dunkerque-Bauvin, and Bauvin-Halluin), and lowest on the double lock complexes on the Bauvin-Mortagne branch (Douai, Courchelettes, Goeulzin).

Secondary results are the lock chamber occupancy, water consumption, distribution of the number of waiting ships at locks, etc.

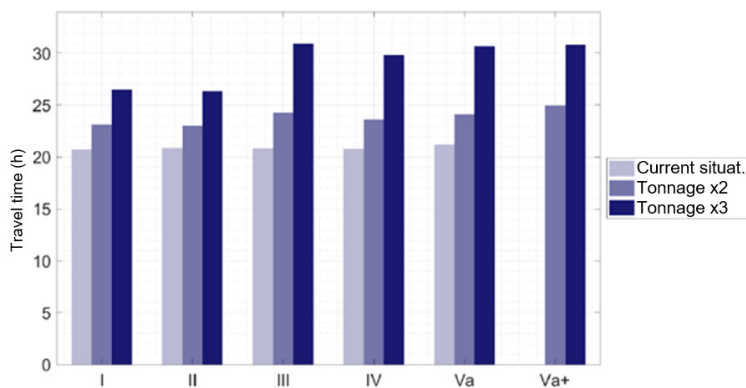


Figure 3: increase of travel time (hours) between Dunkerque and Valenciennes due to increase of traffic

The actual network has been tested for increased traffic (cargo multiplied by 2 and 3, redistributed over a fleet structure taking into account the overall increase in ship size). This leads to a significant increase of the waiting times at the Flandres, Fontinettes and Cuinchy locks (Bauvin - Dunkerque branch), and at Don and Grand Carré (Bauvin - Halluin branch), which then welcomes a larger proportion of class V ships coming from the new Canal Seine Nord Europe.

Simulations for increased traffic have been executed with a 24h/24h lock service. A sensitivity analysis on night navigation

allowed to parametrise and formulate a hypothesis on the distribution of the number of ships sailing during the night. The results allowed to highlight the interest of night navigation to accommodate future traffic.

The simulations show that chances of ships encounters in narrow canal sections are fairly limited. Such encounters on the canal do not lead to significant increases of travel time. Capacity curves show that the so called comfort capacity of the lock complexes (less than 10% of ships wait for one lock cycle or more at locks) is already close to being reached today at several locks of the Bauvin - Dunkerque and Bauvin-Halluin branches (Cuinchy, Fontinettes, Flandres, resp. Don, Grand Carré, Quesnoy).

### Feedback from the trajectory analysis to the traffic flow model

Feedback from the nautical simulations to the traffic flow model is the next step in the development of the models.

The traffic flow is now being modelled using the possible ship encounters resulting from the desk top study. The nautical accessibility from the nautical simulations can be used to refine this.

Now velocity is being imposed by the speed limits from the police regulations (maximum speed) and Schijf's velocity (lower speed defined by wet cross section and ship characteristics), but this can be refined by taking into account speed reduction during encounters as simulated during the nautical simulations.

Further investigations could include: the study of the effect of adapting speed limits (while staying below speeds potentially causing damage to the banks), the study the effect of imposed speed on the traffic flow (traffic regulation study), the study of the effect of giving priority to larger ships at locks, etc.

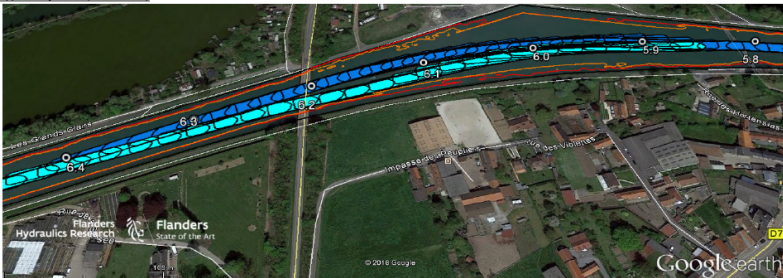
Ref/bon de commande		Date de commande		Secteur		Version		Auteur		Révision		Approbation	
18 31 0002697		9/05/2018		Pont - Malin - Mardyck		2.0		Marc Mansuy		RAD		SEP	
Ref livrable		Date de soumission											
U/RA/12152/18.083/SEP/		31/08/2018											
Etude de trajectographie sur le réseau navigable du Nord Pas de Calais													
Section 20 (PK5.8-6.3)													
Accessibilité étudiée: Va-IV													
Protocole													
Unités:													
# sim		Unité		Chargement		Simulateur		Croisement					
		Montant	Descendant	Montant	Descendant	Montant	Descendant	PK					
001		IV	Va	chargé	chargé	SIM225	LARA	6.0					
002		Va	IV	chargé	chargé	LARA	SIM225	6.0					
003		Va	IV	chargé	chargé	LARA	SIM225	6.1					
017		Va	Va	chargé	chargé	SIM225	LARA	6.1					
018		Va	Va	chargé	chargé	SIM225	LARA	6.1					
Conditions hydrométéorologiques:													
Niveau d'eau		Courant	Vent	Visibilité									
NNN		<0.1 m/s	SO4	normale									
Simulations													
Illustration de l'enveloppe de trajectoire. (simulation18)													
													
Evaluation des pilotes:													
# sim		Réserve	Difficulté	Commentaire des pilotes									
001		2	2										
002		2	2										
003		2	2										
017		2	2										
018		2	2	Cette section devrait être draguée mais en réalité même si un bateau touche, si c'est du sable ça disparaît après le passage régulier d'unité Va. Le croisement semble possible aussi sous le pont.									
Commentaire de l'opérateur:													
# sim		Commentaire de l'opérateur											
001													
002		Positions initiales inversées (répétabilité).											
003		Point de rencontre plus proche du pont											
017		Essai encore plus proche du pont.											
018		Le rétrécissement sous eau n'est pas visible en réalité. Un dragage semble nécessaire.											
Analyse des résultats													
Indicateurs de succès:													
# sim		Vitesse [km/h]	Dégagement sous quille [m]	Distance au contour à 3m [m]	Distance au contour à 2.5m/1.7m [m]	Réserve propulseur principal	Réserve propulseur d'étrave	Réserve gouvernail	Réserve moyenne	Variation moyenne du gouvernail [°/s]	Distance entre bateaux [m]		
Unité montante													
001		7.6	0.9	0.3	3.0	44%	100%	85%	83%	1.64	9.7		
002		6.0	0.7	0.6	1.4	63%	100%	86%	87%	1.58	6.5		
003		6.8	1.0	0.8	4.1	56%	100%	86%	86%	1.95	6.9		
017		7.9	1.0	1.9	3.5	41%	100%	88%	84%	1.79	4.7		
018		7.9	0.8	0.6	1.8	40%	100%	97%	84%	2.19	6.1		
Unité descendante													
001		9.0	1.0	6.7	8.0	42%	100%	92%	86%	1.73	9.7		
002		7.6	1.0	6.1	7.8	43%	100%	86%	83%	2.71	6.5		
003		7.9	1.0	4.5	8.1	45%	100%	88%	84%	1.81	6.9		
017		7.0	1.0	6.3	7.9	50%	100%	93%	88%	1.34	4.7		
018		7.1	1.0	4.9	9.1	53%	100%	92%	88%	1.87	6.1		
Conclusion													
Evaluation de l'expert nautique:													
# sim		Evaluation de l'expert nautique		Commentaire de l'expert nautique									
001				Croisement sans contrainte.									
002				Croisement acceptable à faible vitesse, variations rapides du gouvernail.									
003				Croisement sans contrainte.									
017				Double sens Va possible.									
018				Il y a assez d'espace pour un double sens sur la section 20. Variations rapides du gouvernail.									
Accessibilité retenue: Va-Va													

Figure 4: example of simulation result sheet (in French), combining visuals of the sailed trajectory and an appreciation of the accessibility level using a colour scale: from top to bottom: the "protocole", this is an overview of simulated situations (ship types, direction, load); "simulations" section giving an example of a simulated swept path, and an overview of comments on the difficulty as appreciated by the pilots and the nautical expert; the "analysis of the results" indicating the exceedance of thresholds defined for Under Keel Clearance, distance to depth contours, reserves for engine, rudder, distance between ships, with a colour scale; and finally the "conclusion", an evaluation of the navigability of the section by the nautical expert